Memorandum

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DATE:	November 20, 2008
TO:	Central Valley Drinking Water Policy Work Group
SUBJECT:	Projected 2030 Source Water Quality
cc:	

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OBJECTIVE

The Central Valley Drinking Water Policy Work Group's (CVDWPWG) "water quality scenarios" subgroup has completed a number of tasks related to data collection and data compilation that built upon previous efforts for the development of conceptual models of the Sacramento-San Joaquin River Delta for nutrients, salinity, organic carbon, and pathogen indicators. This work was performed to provide necessary baseline and future water quality information to Malcolm Pirnie, Inc. (MPI), the consultant hired by the CVDWPWG to assess impacts of possible future changes in source water quality to drinking water treatment plant design and operation.

This technical memorandum describes and summarizes results from a "spreadsheet" model developed to provide MPI with projected median and 90th percentile concentrations in 2030 for the constituents of interest under "degraded" and "improved" ambient water quality scenarios. This information is needed at this time to allow MPI to complete their scope of work, which is ongoing.

Future work efforts by the CVDWPWG will include using more detailed analytical models to refine projections of future water quality changes at specified drinking water intake locations under various management scenarios.

METHODOLOGY

This spreadsheet modeling effort uses previous water quality and source load data compilations, conceptual modeling results, and available planning information to estimate *incremental changes* in source loads by 2030 and the resulting effect on observed historical ambient water quality concentrations for constituents of interest. This spreadsheet model is intended to provide preliminary projections of changes to ambient water quality concentrations and consider source load seasonal variability. A more sophisticated numerical model will be developed in a future effort by the CVDWPWG.

The spreadsheet model is organized to provide information for the following locations in the Central Valley:

- Sacramento River at Hood (Hood);
- San Joaquin River at Vernalis (Vernalis);
- In-Delta at Harvey O. Banks Pumping Plant (Banks);
- North Bay Aqueduct at Barker Slough (Barker);
- West Branch of the California Aqueduct (Castaic Lake); and
- East Branch of the California Aqueduct (Check 13).

These locations coincide with subareas being evaluated under the MPI scope.

For each location except Banks, projected median concentrations are calculated as historical median concentrations plus incremental concentration changes based on projected 2030 loads and historic critical dry and wet year river flows. For the Banks location, the "fingerprint flow sources" are obtained directly from California Department of Water Resources (DWR) historic flow models for the 1992 critical dry water year and 1998 wet water year. The fingerprint is applied to the estimated source loads from each source node considered to estimate the future incremental concentration change at the Banks location.

Projected changes in the median ambient water quality concentrations for parameters of concern were then used to shift baseline distributions and estimate projected 90th percentile values from existing ambient water quality data at each location.

These 2030 projections are based on "degraded" and "improved" conditions resulting from changes in population, urbanization, and various management actions. The "degraded" condition assumes no changes beyond existing and planned treatment and source control. The "improved" condition assumes more advanced treatment and more rigorous source control than is currently planned. A description of the assumptions used for each condition is included below in the discussion of assumptions and the sensitivity analysis (Attachment A). Both conditions involve projecting changes in the following three types of sources using water years 1992 and 1998 *daily river flows*:

- Treated wastewater discharges;
- Urban runoff; and
- Agricultural runoff.

Treated Wastewater Discharges

Projected 2030 load calculations from treated wastewater were based on assumed per capita daily wastewater flow rates and population growth rates to estimate the 2030 effluent flow rate. This flow rate was applied to primarily literature-based constituent concentrations based on treatment technology to estimate an effluent load for each wastewater treatment facility. A summary of the load calculations for each wastewater treatment facility is provided in Attachment B. The key assumptions to the calculation methodology are discussed in the section below.

Urban Runoff

Projected 2030 urban runoff load calculations were based on hydrologic modeling performed as part of the Sacramento Stormwater Quality Partnership Discharge Characterization Program (DCP) continuous simulation model on a daily time step based on observed rainfall for a critical dry year (1992) and a wet year (1998). Daily dry weather flows were assumed constant with unique values for the wet and dry season. These daily urban area runoff volumes were scaled to match the projected 2030 urban area. The projected daily flows were multiplied by the median observed concentration to calculate a daily load. Load reduction factors were applied to the existing development area to account for improved management and system retrofit, and to the projected new development to account for development standards that remove volume and load from the discharge. The Sacramento results were then scaled to the in-Delta and San Joaquin urban areas with adjustments to account for lower annual precipitation and system “losses” through infiltration. A sample calculation is provided in Attachment C. The key assumptions to the calculation methodology are discussed in the section below.

Agricultural Runoff

Projected 2030 agricultural runoff load calculations were based on agricultural area estimates developed by the Department of Conservation Farmland Mapping Program and constituent export rates developed in the conceptual models. For the in-Delta subarea, agricultural runoff flow rates estimated by DWR’s Delta Island Consumptive Use (DICU) model and multiplied by median observed concentration to calculate a daily load. Load reduction factors were applied to existing areas to account for improved management and system retrofit. A sample calculation is provided in Attachment D. The key assumptions to the calculation methodology are discussed in the section below.

KEY ASSUMPTIONS

This section lists the key assumptions that were made in developing the spreadsheet model for each constituent loading source for each subarea of interest. The treated wastewater discharges and urban runoff assumptions used in model development are generally conservative. These spreadsheet model results are only intended to estimate the range of potential changes to in-stream concentrations, and are not appropriate for use as quantitative measurements of specific source loads. Specifically, the results only "bracket" the upper and lower ranges of projected 2030 concentrations for planning purposes. It is likely that this spreadsheet model and the assumptions described below overestimate the contributions from the wastewater and urban runoff. More detailed analyses of available information will also be needed to develop scenarios for the sensitivity analyses that will be conducted using analytical modeling tools under development.

Treated Wastewater Discharges

- 2004 and 2024 populations for each wastewater treatment facility are provided in the 2004 USEPA Needs Survey (available at: http://www.epa.gov/OW-OWM.html/mtb/cwns/2004rtc/toc.htm). An annual population growth rate was calculated for each wastewater treatment facility based on these end point population estimates. Using the calculated population growth rate, 2008 and 2030 population estimates were calculated for each treatment plant.
- 2004 total effluent flow data are also provided in the 2004 USEPA Needs Survey. A 2004 total daily per capita wastewater flow (e.g., including industrial flow) was calculated using the 2004 population and flow data. The 2004 total wastewater flow per capita was used to estimate total daily flow volume for 2008 (current) and 2030 "degraded" condition.
- Effluent water quality data primarily came from three sources: NPDES permits, LWA-compiled data sets (e.g., data sets from submitted reports such as Reports of Waste Discharge), or literature values from Metcalf & Eddy (*Wastewater Engineering: Treatment and Reuse*, 2002) based on treatment technology. It should be noted that NPDES permits sometimes only contained maximum effluent concentrations for the constituents of interest, which will result in overestimation of effluent constituent loadings.
- Constituent loads were calculated for the current 2008 condition and projected 2030 "degraded" condition using the current total daily wastewater flow per capita values for each wastewater treatment facility. For the projected 2030 "degraded" condition, it was assumed that only wastewater treatment plant upgrades currently planned will be implemented.
- Two treated wastewater discharge conditions were developed for the projected 2030 "improved" condition by assuming a daily wastewater flow per capita of either 80 or 100 gallons/capita/day. In both conditions, all wastewater treatment facilities are upgraded to a minimum treatment of filtration with nitrogen removal (i.e., nitrification/denitrification, which removes most total nitrogen). Under both scenarios, total dissolved solids (TDS) loadings were kept constant since the proposed treatment processes considered will not reduce TDS.
- Seasonal discharges were accounted for, to the best extent possible for this effort, if there were specific periods during the year in which a wastewater treatment facility was prohibited from discharging to the receiving water. Actual

seasonal discharge situations were not identified, which may result in overestimation of effluent constituent loadings.

- The wastewater effluent loading analysis does not completely account for all current or future recycled water efforts. As such, surface water discharge constituent loadings are overestimated by the amount of future recycling that actually happens.
- Facility by facility data sources and sample calculations are presented in Attachment B.

Urban Runoff

- The Department of Conservation Farmland Mapping Program (http://www.conservation.ca.gov/dlrp/fmmp/Pages/Index.aspx) maps urban area by county every two years. Based on historic urban area size data, an annual urban area growth rate was estimated. Using this calculated annual growth rate, 2008 and 2030 urban area sizes were estimated for each subarea using a detailed 2002 land use map developed by the California Department of Forestry and Fire Protection Fire and Resource Assessment Program. This base layer map was also used in the conceptual modeling effort.
- The DCP model was used in the preparation of the Antidegradation Analysis for the Sacramento Stormwater Program in 2007. The model of observed loads was adapted to project urban runoff volume based on precipitation and hydrologic data from water years 1992 and 1998 that were "scaled" to the projected 2030 urban area. For the San Joaquin and in-Delta subareas, factors of 0.7 and 0.9, respectively, were used to adjust urban runoff volume to account for variation in precipitation totals as compared to precipitation in the Sacramento River watershed.
- For the San Joaquin and in-Delta subareas, a second factor of 0.7 was used to adjust urban runoff volume to account for non-surface water discharges (i.e., detention basins, rock wells, irrigation channels) that are more prevalent in those areas than the Sacramento urban area.
- From the DCP model, dry weather (wet season) and dry weather (dry season) urban runoff volumes were estimated to be 25,400 and 21,400 $ft^3/mi^2/day$, respectively based on observed data before 1996.
- Urban runoff water quality median concentration data from the Sacramento Stormwater Quality Partnership were used for the San Joaquin River watershed and in-Delta subareas.
- Load reduction factors were applied separately to existing and projected new development through 2030 to account for anticipated reductions in flow and load through management programs, system retrofit, and new development standards. Flow reductions through low impact development (LID) standards are expected in this project horizon. These assumptions are intended to include the range of possible values. The assumed 2030 load reduction factors are presented in Table 1.

Table 1. Assumed 2030 Load Reduction Factors

Constituent	Degraded Condition		Improved Condition	
	Existing Developed Area	New Development Area	Existing Developed Area	New Development Area
Total Organic Carbon	0%	10%	10%	50%
Total Phosphorus	0%	10%	10%	50%
Total Nitrogen	0%	10%	10%	50%
Total Dissolved Solids	0%	0%	0%	0%

- Sample calculations for urban runoff load estimates are presented in Attachment C.

Agriculture

- The Department of Conservation Farmland Mapping Program estimates agricultural area by county every two years. Based on historic agricultural area size data, an annual reduction rate was estimated. Using this calculated annual reduction rate, 2008 and 2030 agricultural area sizes were estimated for each subarea using a detailed 2002 land use map developed by the California Department of Forestry and Fire Protection Fire and Resource Assessment Program. This base layer map was also used in the conceptual modeling effort.
- Agricultural source quality data from Colusa Basin Drain (Drinking Water Quality Policy Database) were used to estimate agricultural loads contributing to the Sacramento River.
- Agricultural source quality data from Orestimba Creek (Drinking Water Quality Policy Database) were used to estimate agricultural loads contributing to the San Joaquin River.
- Agricultural source quality data from Staten Island (Drinking Water Quality Policy Database) were used to estimate agricultural loads contributing directly to the Delta from in-Delta areas.
- For the projected 2030 “degraded” condition, it was assumed that agricultural loads would not change with the exception of the reduction in agricultural land area converted to urban uses.
- For the projected 2030 “improved” condition, agricultural load reductions were assumed based on each constituent and the expectation of some BMP implementation. Total organic carbon and TDS loadings were not expected to be reduced in the future condition. Total nitrogen and total phosphorus loadings were assumed to be reduced by 20% and 10%, respectively (CALFED, 2008).

Ambient Waters

- Ambient water quality conditions for Hood, Vernalis, Banks, Barker, Castaic Lake, and Check 13 were compiled by the water quality scenarios subgroup using data from the Drinking Water Quality Policy Database and other sources. This information was used to represent the baseline water quality condition at each location.
- DWR uses a model to approximate the source and quantity of flow entering the Banks Pumping Plant. This "fingerprinting" model was used to estimate the incremental load changes at Banks from Sacramento River, San Joaquin River, and in-Delta sources. It was assumed that there is no incremental load changes from San Francisco Bay influences (at Martinez), Eastside streams (Cosumnes River, Stanislaus River, and Mokelumne River), and Jones Tract.
- The incremental concentration changes at Banks were assumed to also apply for the California Aqueduct (West Branch – Castaic Lake and East Branch – Check 13). The incremental concentration changes at Banks are directly applied to the baseline water quality condition at these two sites.
- It was assumed that the Barker Slough watershed was completely agricultural. As such, for the projected 2030 "degraded" condition, no change from the baseline water quality condition is expected for the North Bay Aqueduct at Barker Slough. For the projected 2030 "improved" condition, the agricultural load reductions previously stated were applied to the baseline water quality to develop projected 2030 ambient water quality concentrations.
- The fate and transport of the constituents of interest were not considered in the spreadsheet model.

RESULTS

The results of this spreadsheet modeling effort are provided in Table 2 through Table 7.

The projected 2030 median load change at Hood, Vernalis, and Banks using a daily per capita wastewater flow rate of 80 gallons/capita/day is presented in Table 2. The projected 2030 median ambient concentrations and incremental concentration changes at the water intake points using a daily per capita wastewater flow rate of 80 gallons/capita/day are presented in Table 3. The projected 2030 90th percentile ambient concentrations and incremental concentration changes at the water intake using a daily per capita wastewater flow rate of 80 gallons/capita/day are presented in Table 4.

The projected 2030 median load change at Hood, Vernalis, and Banks using a daily per capita wastewater flow rate of 100 gallons/capita/day is presented in Table 5. The projected 2030 median ambient concentrations and incremental concentration changes at the water intake points using a daily per capita wastewater flow rate of 100 gallons/capita/day are presented in Table 6. The projected 2030 90th percentile ambient concentrations and incremental concentration changes at the water intakes using a daily per capita wastewater flow rate of 100 gallons/capita/day are presented in Table 7.

Table 2. Projected 2030 Median Incremental Loading Change (in lb/day) at Water Intake Locations (low daily wastewater per capita)[1]

Scenario	Total Organic Carbon		Total Phosphorus as P		Total Nitrogen as N		Total Dissolved Solids	
	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year
Current Condition								
Sacramento River at Hood	110,000	330,000	5,800	17,000	35,000	110,000	4,700,000	15,000,000
San Joaquin River at Vernalis	18,000	160,000	1,000	11,000	12,000	99,000	2,300,000	13,000,000
2030 Degraded Condition[2]								
Sacramento River at Hood	10,000	16,000	1,600	1,500	12,000	10,000	290,000	310,000
San Joaquin River at Vernalis	-3,600	-5,100	300	100	-3,700	-3,000	80,000	63,000
In-Delta	2,400	2,700	800	800	1,700	1,700	220,000	220,000
2030 Improved Condition								
Sacramento River at Hood	-26,000	-25,000	-400	-800	-24,000	-27,000	290,000	310,000
San Joaquin River at Vernalis	-8,600	-9,800	-400	-600	-6,400	-7,800	80,000	63,000
In-Delta	-1,400	-1,200	-10	-10	-3,400	-3,400	220,000	220,000

[1]Assuming a daily wastewater per capita flow rate of 80 gallons/capita/day.

[2]Projected load changes may be negative (i.e., load decreases) in the 2030 "degraded" condition due to changes in urban runoff, assumed management programs, and planned upgrades to wastewater treatment facilities.

Table 3. Projected 2030 Median Concentrations (in mg/L) at Water Intake Locations (low daily wastewater per capita)[1,2]

Scenario	Total Organic Carbon		Total Phosphorus as P		Total Nitrogen as N		Total Dissolved Solids	
	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year
Sacramento River at Hood								
Current	2.0	1.9	0.11	0.09	0.8	0.6	99	85
2030 Degraded Condition								
Incremental Change	0.2	0.1	0.03	0.01	0.2	0.1	6	1
Final Concentration	2.2	2.0	0.14	0.10	1.0	0.7	105	86
2030 Improved Condition								
Incremental Change	-0.5	-0.2	-0.01	-0.01	-0.4	-0.2	6	1
Final Concentration	1.5	1.8	0.10	0.09	0.3	0.4	106	86
San Joaquin River at Vernalis								
Current	3.9	3.4	0.22	0.23	2.6	1.7	430	272
2030 Degraded Condition								
Incremental Change	-0.7	-0.1	0.02	<0.01	-0.5	<0.1	15	1
Final Concentration	3.2	3.3	0.24	0.24	2.1	1.7	445	273
2030 Improved Condition								
Incremental Change	-1.7	-0.2	-0.10	-0.01	-1.2	-0.1	15	1
Final Concentration	2.2	3.2	0.12	0.23	1.5	1.6	445	273
Banks Pumping Plant								
Current	3.2	3.4	0.10	0.11	0.9	0.9	253	204
2030 Degraded Condition								
Incremental Change	0.3	0.1	0.08	0.03	0.3	0.1	18	10
Final Concentration	3.5	3.6	0.18	0.14	1.2	1.0	272	213
2030 Improved Condition								
Incremental Change	-0.6	-0.2	-0.01	-0.01	-0.5	-0.2	20	11
Final Concentration	2.6	3.2	0.09	0.10	0.4	0.7	274	214

Table 3. Projected 2030 Median Concentrations (in mg/L) at Water Intake Locations (low daily wastewater per capita)[1,2]

Scenario	Total Organic Carbon		Total Phosphorus as P		Total Nitrogen as N		Total Dissolved Solids	
	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year
Barker Slough								
Current	5.1	6.8	0.18	0.19	0.9	0.9	186	175
2030 Degraded Condition								
Incremental Change	<0.1	<0.1	<0.01	<0.01	<0.1	<0.1	<1	<1
Final Concentration	5.1	6.8	0.18	0.19	0.9	0.9	186	175
2030 Improved Condition								
Incremental Change	<0.1	<0.1	-0.02	-0.02	-0.2	-0.2	<1	<1
Final Concentration	5.1	6.8	0.16	0.17	0.7	0.7	186	175
California Aqueduct (West Branch - Castaic Lake)								
Current	2.9	3.1	0.04	0.03	0.7	0.6	287	294
2030 Degraded Condition								
Incremental Change	0.3	0.1	0.08	0.03	0.3	0.1	18	10
Final Concentration	3.2	3.2	0.12	0.07	0.9	0.6	306	303
2030 Improved Condition								
Incremental Change	-0.6	-0.2	-0.01	-0.01	-0.5	-0.2	20	11
Final Concentration	2.3	2.9	0.03	0.03	0.2	0.3	308	304
California Aqueduct (East Branch - Check 13)								
Current	3.6	3.7	0.08	0.10	0.6	1.0	305	224
2030 Degraded Condition								
Incremental Change	0.3	0.1	0.08	0.03	0.3	0.1	18	10
Final Concentration	3.9	3.8	0.16	0.14	0.8	1.1	323	234
2030 Improved Condition								
Incremental Change	-0.6	-0.2	-0.01	-0.01	-0.5	-0.2	20	11
Final Concentration	3.0	3.5	0.07	0.09	<0.1	0.8	325	235

[1]Assuming a daily wastewater per capita flow rate of 80 gallons/capita/day.

[2]The sum of the current concentration and the incremental change may not appear to add up to the final concentration due to rounding.

Table 4. Projected 2030 90th Percentile Concentrations (in mg/L) at Water Intake Locations (low daily wastewater per capita)[1,2]

Scenario	Total Organic Carbon		Total Phosphorus as P		Total Nitrogen as N		Total Dissolved Solids	
	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year
Sacramento River at Hood								
Current	3.1	2.8	0.20	0.15	1.1	1.0	124	108
2030 Degraded Condition								
Incremental Change	0.2	0.1	0.03	0.01	0.2	0.1	6	1
Final Concentration	3.2	2.9	0.23	0.16	1.3	1.1	130	109
2030 Improved Condition								
Incremental Change	-0.5	-0.2	-0.01	-0.01	-0.4	-0.2	6	1
Final Concentration	2.5	2.7	0.19	0.15	0.7	0.8	130	109
San Joaquin River at Vernalis								
Current	6.3	4.8	0.35	0.53	4.0	3.4	651	540
2030 Degraded Condition								
Incremental Change	-0.7	-0.1	0.02	<0.01	-0.5	-0.1	15	1
Final Concentration	5.6	4.7	0.37	0.53	3.4	3.4	666	541
2030 Improved Condition								
Incremental Change	-1.7	-0.2	-0.10	-0.01	-1.2	-0.1	15	1
Final Concentration	4.6	4.6	0.25	0.52	2.8	3.3	667	541
Banks Pumping Plant								
Current	4.7	5.1	0.14	0.16	1.8	1.6	422	348
2030 Degraded Condition								
Incremental Change	0.3	0.1	0.08	0.03	0.3	0.1	18	10
Final Concentration	4.9	5.2	0.22	0.20	2.1	1.7	440	358
2030 Improved Condition								
Incremental Change	-0.6	-0.2	-0.01	-0.01	-0.5	-0.2	20	11
Final Concentration	4.0	4.8	0.13	0.16	1.3	1.4	442	359

Table 4. Projected 2030 90th Percentile Concentrations (in mg/L) at Water Intake Locations (low daily wastewater per capita)[1,2]

Scenario	Total Organic Carbon		Total Phosphorus as P		Total Nitrogen as N		Total Dissolved Solids	
	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year
Barker Slough								
Current	10	15	0.29	0.35	1.4	1.5	264	265
2030 Degraded Condition								
Incremental Change	0.3	<0.1	<0.01	<0.01	<0.1	<0.1	<1	<1
Final Concentration	11	15	0.29	0.35	1.4	1.5	264	265
2030 Improved Condition								
Incremental Change	<0.1	<0.1	-0.03	-0.03	-0.3	-0.3	<1	<1
Final Concentration	10	15	0.26	0.31	1.1	1.2	264	265
California Aqueduct (West Branch - Castaic Lake)								
Current	3.7	3.9	0.08	0.07	0.8	0.8	321	330
2030 Degraded Condition								
Incremental Change	0.3	0.1	0.08	0.03	0.3	0.1	18	10
Final Concentration	4.0	4.0	0.15	0.11	1.1	0.9	340	339
2030 Improved Condition								
Incremental Change	-0.6	-0.2	-0.01	-0.01	-0.5	-0.2	20	11
Final Concentration	3.1	3.7	0.06	0.06	0.3	0.6	342	340
California Aqueduct (East Branch - Check 13)								
Current	5.3	5.5	0.09	0.16	0.9	1.7	414	335
2030 Degraded Condition								
Incremental Change	0.3	0.1	0.08	0.03	0.3	0.1	18	10
Final Concentration	5.5	5.6	0.17	0.19	1.2	1.8	432	345
2030 Improved Condition								
Incremental Change	-0.6	-0.2	-0.01	-0.01	-0.5	-0.2	20	11
Final Concentration	4.7	5.2	0.08	0.15	0.4	1.5	434	346

[1]Assuming a daily wastewater per capita flow rate of 80 gallons/capita/day.

[2]The sum of the current concentration and the incremental change may not appear to add up to the final concentration due to rounding.

Table 5. Projected 2030 Median Incremental Loading Change (in lb/day) at Water Intake Locations (high daily wastewater per capita)[1]

Scenario	Total Organic Carbon		Total Phosphorus as P		Total Nitrogen as N		Total Dissolved Solids	
	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year
Current Condition								
Sacramento River at Hood	110,000	330,000	5,800	17,000	35,000	110,000	4,700,000	15,000,000
San Joaquin River at Vernalis	18,000	160,000	1,000	11,000	12,000	99,000	2,300,000	13,000,000
2030 Degraded Condition[2]								
Sacramento River at Hood	12,000	20,000	1,700	1,800	12,000	10,000	290,000	310,000
San Joaquin River at Vernalis	-3,300	-4,800	300	100	-3,700	-3,000	80,000	63,000
In-Delta	2,900	3,200	800	800	1,700	1,700	220,000	220,000
2030 Improved Condition								
Sacramento River at Hood	-22,000	-21,000	700	300	-21,000	-24,000	290,000	310,000
San Joaquin River at Vernalis	-7,600	-9,100	-300	-400	-6,100	-7,200	80,000	63,000
In-Delta	300	500	500	500	-1,800	-1,800	220,000	220,000

[1]Assuming a daily wastewater per capita flow rate of 100 gallons/capita/day.

[2]Projected load changes may be negative in the 2030 “degraded” condition due to changes in urban runoff, assumed management programs, and planned upgrades to wastewater treatment facilities.

Table 6. Projected 2030 Median Concentrations (in mg/L) at Water Intake Locations (high daily wastewater per capita)[1,2]

Scenario	Total Organic Carbon		Total Phosphorus as P		Total Nitrogen as N		Total Dissolved Solids	
	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year
Sacramento River at Hood								
Current	2.0	1.9	0.11	0.09	0.8	0.6	99	85
2030 Degraded Condition								
Incremental Change	0.2	0.1	0.03	0.01	0.2	0.1	6	1
Final Concentration	2.2	2.0	0.14	0.10	1.0	0.7	105	86
2030 Improved Condition								
Incremental Change	-0.4	-0.1	0.01	0.00	-0.4	-0.2	6	1
Final Concentration	1.6	1.8	0.13	0.09	0.4	0.5	106	86
San Joaquin River at Vernalis								
Current	3.9	3.4	0.22	0.23	2.6	1.7	430	272
2030 Degraded Condition								
Incremental Change	-0.6	-0.1	0.02	<0.01	-0.5	<0.1	15	1
Final Concentration	3.3	3.3	0.24	0.24	2.1	1.7	445	273
2030 Improved Condition								
Incremental Change	-1.5	-0.2	-0.07	-0.01	-1.1	-0.1	15	1
Final Concentration	2.4	3.2	0.15	0.23	1.6	1.6	445	273
Banks Pumping Plant								
Current	3.2	3.4	0.10	0.11	0.9	0.9	253	204
2030 Degraded Condition								
Incremental Change	0.3	0.1	0.08	0.04	0.3	0.1	18	10
Final Concentration	3.5	3.6	0.18	0.14	1.2	1.0	272	213
2030 Improved Condition								
Incremental Change	-0.4	-0.1	0.04	0.01	-0.5	-0.2	19	10
Final Concentration	2.8	3.3	0.14	0.12	0.5	0.7	272	214

Table 6. Projected 2030 Median Concentrations (in mg/L) at Water Intake Locations (high daily wastewater per capita)[1,2]

Scenario	Total Organic Carbon		Total Phosphorus as P		Total Nitrogen as N		Total Dissolved Solids	
	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year
Barker Slough								
Current	5.1	6.8	0.18	0.19	0.9	0.9	186	175
2030 Degraded Condition								
Incremental Change	0.3	<0.1	<0.01	<0.01	<0.1	<0.1	<1	<1
Final Concentration	5.4	6.8	0.18	0.19	0.9	0.9	186	175
2030 Improved Condition								
Incremental Change	<0.1	<0.1	-0.02	-0.02	-0.2	-0.2	<1	<1
Final Concentration	5.1	6.8	0.16	0.17	0.7	0.7	186	175
California Aqueduct (West Branch - Castaic Lake)								
Current	2.9	3.1	0.04	0.03	0.7	0.6	287	294
2030 Degraded Condition								
Incremental Change	0.3	0.1	0.08	0.03	0.3	0.1	18	10
Final Concentration	3.2	3.3	0.12	0.07	0.9	0.6	306	303
2030 Improved Condition								
Incremental Change	-0.4	-0.1	-0.01	-0.01	-0.5	-0.2	20	11
Final Concentration	2.5	3.0	0.03	0.03	0.2	0.3	308	304
California Aqueduct (East Branch - Check 13)								
Current	3.6	3.7	0.08	0.10	0.6	1.0	305	224
2030 Degraded Condition								
Incremental Change	0.3	0.1	0.08	0.03	0.3	0.1	18	10
Final Concentration	3.9	3.8	0.16	0.14	0.8	1.1	323	234
2030 Improved Condition								
Incremental Change	-0.4	-0.1	-0.01	-0.01	-0.5	-0.2	20	11
Final Concentration	3.2	3.6	0.07	0.09	<0.1	0.8	325	235

[1]Assuming a daily wastewater per capita flow rate of 100 gallons/capita/day.

[2]The sum of the current concentration and the incremental change may not appear to add up to the final concentration due to rounding.

Table 7. Projected 2030 90th Percentile Concentrations (in mg/L) at Water Intake Locations (high daily wastewater per capita)[1,2]

Scenario	Total Organic Carbon		Total Phosphorus as P		Total Nitrogen as N		Total Dissolved Solids	
	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year
Sacramento River at Hood								
Current	3.1	2.8	0.20	0.15	1.1	1.0	124	108
2030 Degraded Condition								
Incremental Change	0.2	0.1	0.03	0.01	0.2	0.1	6	1
Final Concentration	3.2	2.9	0.23	0.16	1.3	1.1	130	109
2030 Improved Condition								
Incremental Change	-0.4	-0.1	0.01	<0.01	-0.4	-0.2	6	1
Final Concentration	2.6	2.7	0.21	0.15	0.7	0.9	130	109
San Joaquin River at Vernalis								
Current	6.3	4.8	0.35	0.53	4.0	3.4	651	540
2030 Degraded Condition								
Incremental Change	-0.6	-0.1	0.02	<0.01	-0.5	-0.1	15	1
Final Concentration	5.7	4.7	0.37	0.53	3.5	3.4	666	541
2030 Improved Condition								
Incremental Change	-1.5	-0.2	-0.07	-0.01	-1.1	-0.1	15	1
Final Concentration	4.8	4.6	0.28	0.52	2.9	3.3	666	541
Banks Pumping Plant								
Current	4.7	5.1	0.14	0.16	1.8	1.6	422	348
2030 Degraded Condition								
Incremental Change	0.3	0.1	0.08	0.04	0.3	0.1	18	10
Final Concentration	5.0	5.2	0.22	0.20	2.1	1.7	440	358
2030 Improved Condition								
Incremental Change	-0.4	-0.1	0.04	0.01	-0.5	-0.2	19	10
Final Concentration	4.2	4.9	0.18	0.18	1.4	1.4	441	358

Table 7. Projected 2030 90th Percentile Concentrations (in mg/L) at Water Intake Locations (high daily wastewater per capita)[1,2]

Scenario	Total Organic Carbon		Total Phosphorus as P		Total Nitrogen as N		Total Dissolved Solids	
	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year
Barker Slough								
Current	10	15	0.29	0.35	1.4	1.5	264	265
2030 Degraded Condition								
Incremental Change	0.3	<0.1	<0.01	<0.01	<0.1	<0.1	<1	<1
Final Concentration	11	15	0.29	0.35	1.4	1.5	264	265
2030 Improved Condition								
Incremental Change	<0.1	<0.1	-0.03	-0.03	-0.3	-0.3	<1	<1
Final Concentration	10	15	0.26	0.31	1.1	1.2	264	265
California Aqueduct (West Branch - Castaic Lake)								
Current	3.7	3.9	0.08	0.07	0.8	0.8	321	330
2030 Degraded Condition								
Incremental Change	0.3	0.1	0.08	0.04	0.3	0.1	18	10
Final Concentration	4.0	4.1	0.15	0.11	1.1	0.9	340	339
2030 Improved Condition								
Incremental Change	-0.4	-0.1	0.04	0.01	-0.5	-0.2	19	10
Final Concentration	3.3	3.8	0.11	0.09	0.4	0.6	340	339
California Aqueduct (East Branch - Check 13)								
Current	5.3	5.5	0.09	0.16	0.9	1.7	414	335
2030 Degraded Condition								
Incremental Change	0.3	0.1	0.08	0.04	0.3	0.1	18	10
Final Concentration	5.6	5.6	0.17	0.19	1.2	1.8	432	345
2030 Improved Condition								
Incremental Change	-0.4	-0.1	0.04	0.01	-0.5	-0.2	19	10
Final Concentration	4.9	5.3	0.13	0.17	0.5	1.5	432	345

[1]Assuming a daily wastewater per capita flow rate of 100 gallons/capita/day.

[2]The sum of the current concentration and the incremental change may not appear to add up to the final concentration due to rounding.

MODEL VERIFICATION

Three approaches were taken to verify and/or validate the results of the spreadsheet model, and to compare the spreadsheet model results to the conceptual model results. The following methods were used to verify the spreadsheet model, and additional information on these approaches is presented in the following sections:

- Compare actual river loads to estimated source loads for TOC;
- Conduct sensitivity analyses to determine which assumptions are most sensitive inputs to the spreadsheet model; and
- Provide Systech with percent change in wastewater loads for the San Joaquin River at Vernalis.

Compare Actual River Loads to Estimated Source Loads

The first approach used actual receiving water (e.g., Sacramento River and San Joaquin River) TOC concentrations and flows (to calculate actual loads) for water year 2002. The following assumptions were used to perform this model verification step:

- 2002 wastewater flows were estimated using the population growth rates previously calculated (as discussed above) using current per capita wastewater flow values.
- Precipitation totals were approximately the same in 2002 as in 1992. As such, urban runoff volume rates were assumed to be the same as previously modeled. However, the size of the urban area was estimated to 202 levels based on the urban area growth rates previously calculated (as discussed above).
- Agriculture, forest/rangeland, and wetlands source loads were assumed to be the same as the loads estimated in the conceptual model.
- The fate and transport of TOC were not addressed in the spreadsheet model.
- Ambient water quality conditions for Hood and Vernalis were compiled by the water quality scenarios subgroup using data from the Drinking Water Quality Policy Database and other sources.

Wastewater and urban runoff source loads were calculated using the same methodology as the spreadsheet model using a daily time step. Ambient daily TOC loads were calculated using daily flow data and approximately weekly TOC samples collected during water year 2002. The approximately weekly TOC concentrations were used to fill in for days where there were no TOC sample collected. An example of the load calculation is presented in Table 8.

Table 8. Sample Daily Sacramento River at Hood TOC Load Calculation

Date	Concentration (mg/L)[1]	Flow (cfs)	Load (lbs)
08/06/02	**1.2**	12,252	122,694
08/07/02	1.2	12,265	122,823
08/08/02	1.2	11,976	119,924
08/09/02	1.4	11,723	136,959
08/10/02	1.6	11,525	153,875
08/11/02	1.6	11,278	150,579
08/12/02	**1.6**	11,081	147,956
08/13/02	1.6	11,024	147,196

[1]Bolded concentrations are actual sample results.

The results of this model verification step are discussed below:

- For water year 2002, the spreadsheet model underestimated TOC loads in the Sacramento River at Hood by approximately 30%. Wastewater and urban runoff source loads appear to be in-line with the conceptual model in terms of percentage of the total load observed at Hood.
- For water year 2002, the spreadsheet model overestimated TOC loads in the San Joaquin River at Vernalis by approximately 40%. Wastewater and urban runoff source loads appear to be overestimated by the spreadsheet model when compared to the percent of the total observed at Vernalis estimated in the conceptual model. Additionally, forest/rangeland and wetland source load contributions appear to be also overestimated.

Conduct Sensitivity Analyses

Sensitivity analyses were performed to determine the variance resulting form the assumptions that were made. These results are presented in Attachment A.

Provide Systech with Percent Change in Wastewater Load for San Joaquin River at Vernalis Wastewater Dischargers

Information to be filled in pending results.

CONCLUSIONS

The results from this spreadsheet modeling effort are preliminary and are intended to provide MPI with a range of projected conditions using the various assumptions outlined above. Future analytical modeling in the next phase of this effort will refine these results. The preliminary results developed in this effort may also be useful to the CVDWPWG subgroups that are evaluating future control measures and management actions for different source categories.

ATTACHMENT A – SENSITIVITY ANALYSES

Sensitivity analyses were conducted to determine how the key assumptions described in the previous section affect the spreadsheet model. The following variables were each varied individually to determine model performance:

- Using a daily wastewater flow per capita of 100 gallons/day/capita with full filtration and nitrification/denitrification – this variable tests model sensitivity to see if less water conservation than what was projected by 2030 will significantly affect the projected ambient water quality in 2030;
- Increasing/decreasing the urban area for calculation of projected urban runoff loads by 25% – this variable tests model sensitivity to see if increasing/decreasing the urban area at a rate of 25% faster/slower than projected by 2030 will significantly affect the projected ambient water quality in 2030;
- Increasing/decreasing urban runoff concentrations by 25% – this variable tests model sensitivity to see if increasing/decreasing stormwater runoff concentrations by 25% will significantly affect the projected ambient water quality in 2030;
- Increasing/decreasing agricultural area by 25% – this variable tests model sensitivity to see if increasing/decreasing the agricultural area by 25% will significantly affect the projected ambient water quality in 2030; and
- Increasing/decreasing agricultural concentrations by 25% – this variable tests model sensitivity to see if increasing/decreasing agricultural runoff concentrations by 25% will significantly affect the projected ambient water quality in 2030.

The projected 2030 median receiving water concentrations for each of these analyses is presented in Figures A-1 through A-12.

Figure A-1. Projected 2030 Total Organic Carbon Concentrations for Sacramento River at Hood from Sensitivity Analyses

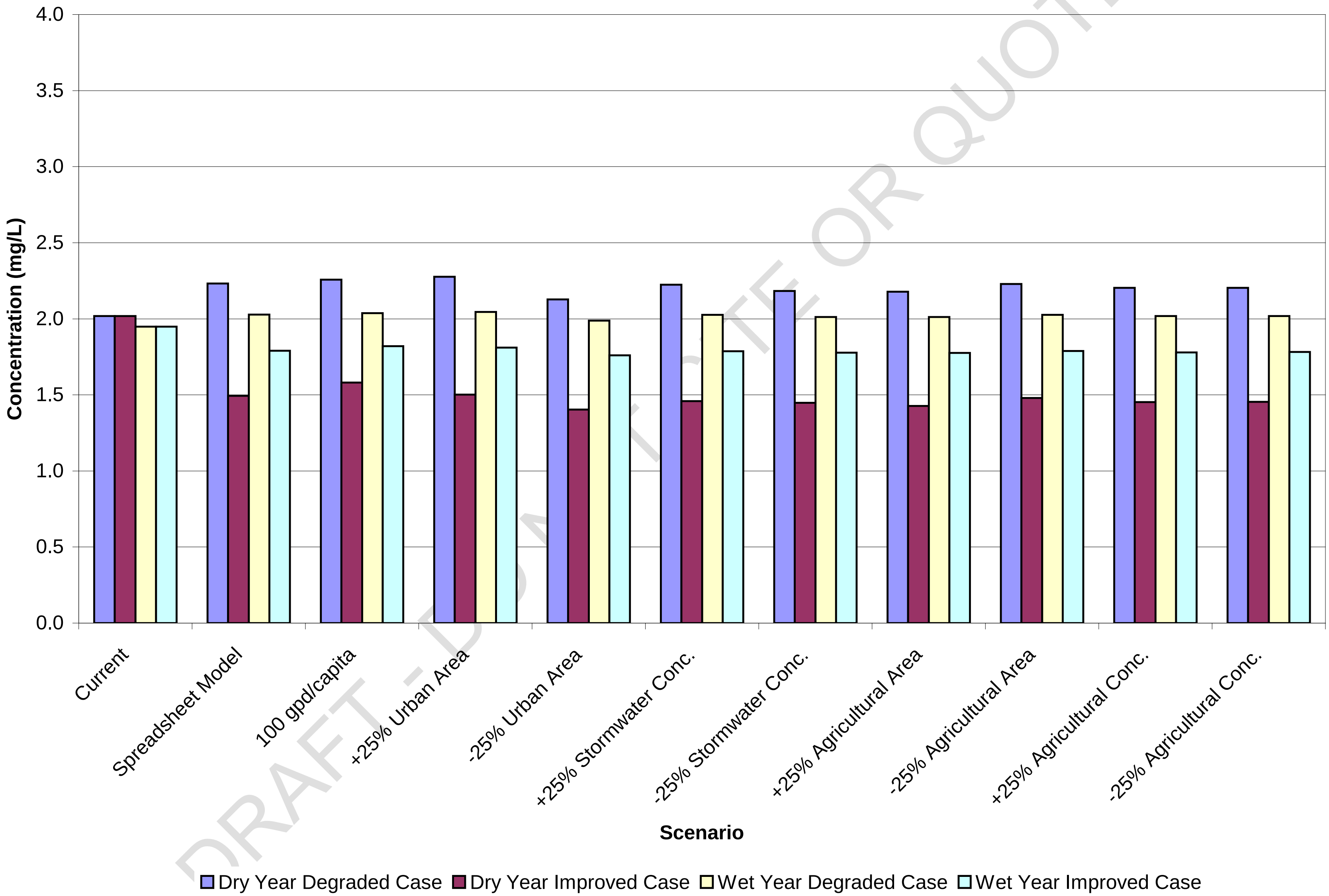


Figure A-2. Projected 2030 Total Organic Carbon Concentrations for San Joaquin River at Vernalis from Sensitivity Analyses

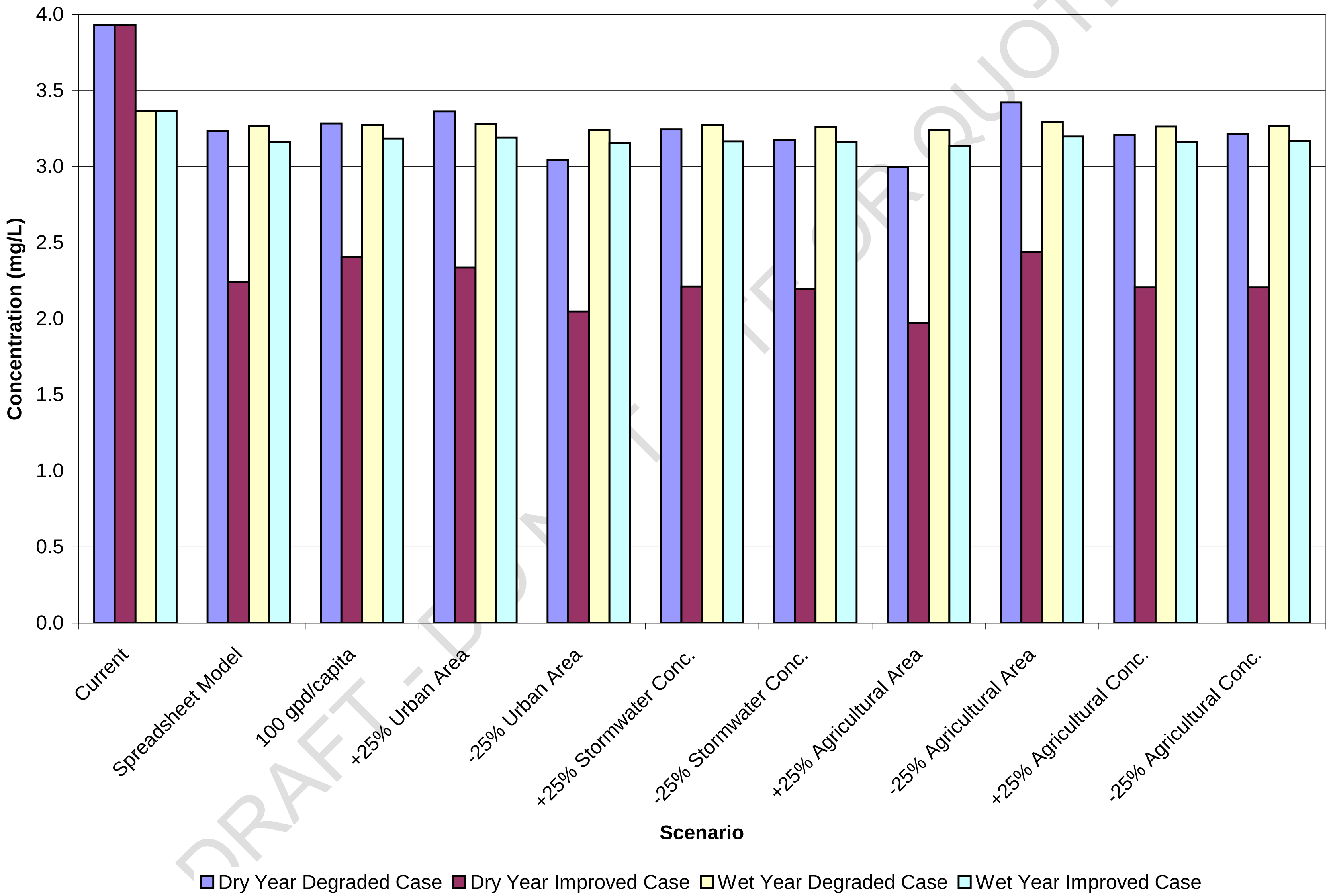


Figure A-3. Projected 2030 Total Organic Carbon Concentrations for Banks Pumping Plant from Sensitivity Analyses

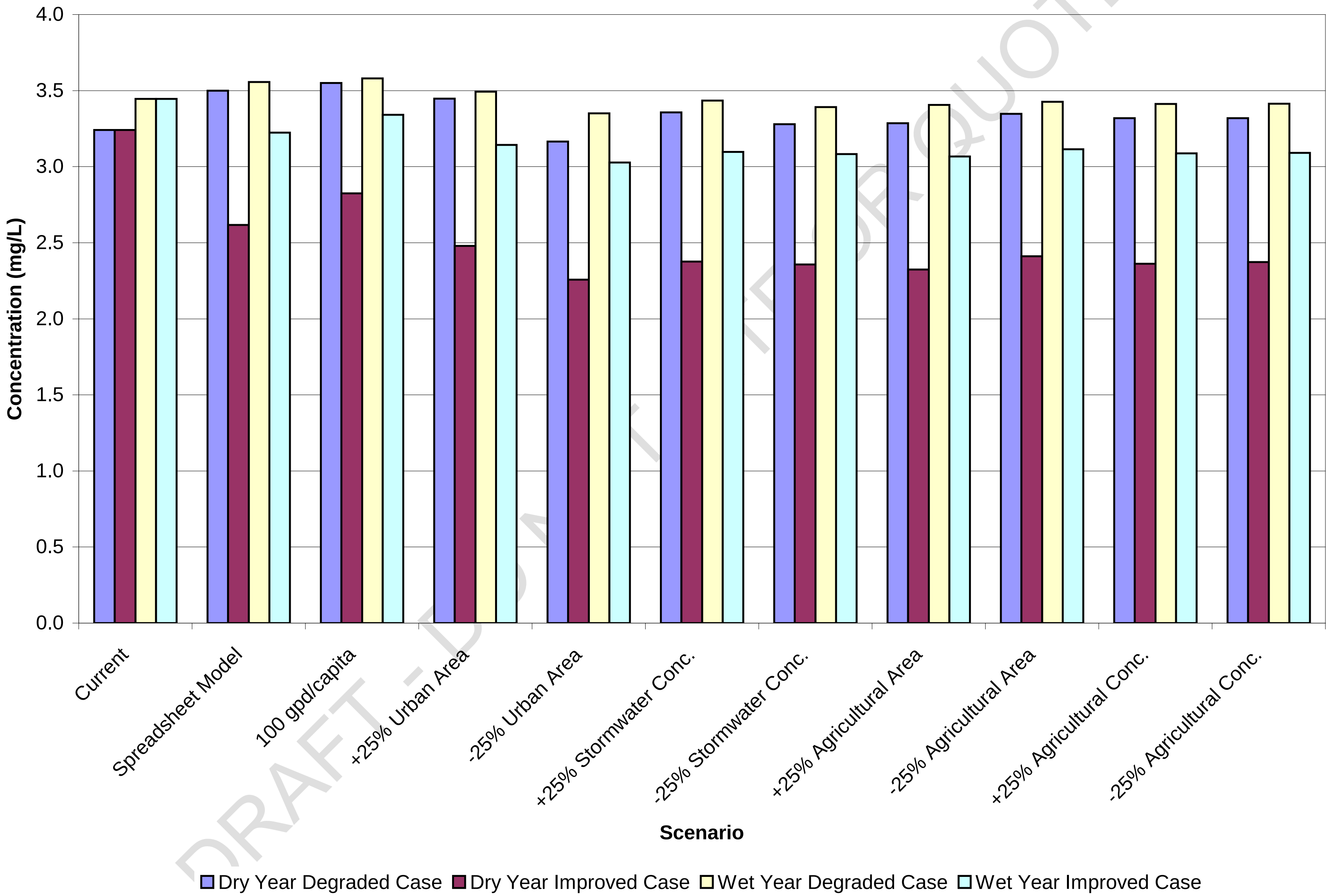


Figure A-4. Projected 2030 Total Phosphorus Concentrations for Sacramento River at Hood from Sensitivity Analyses

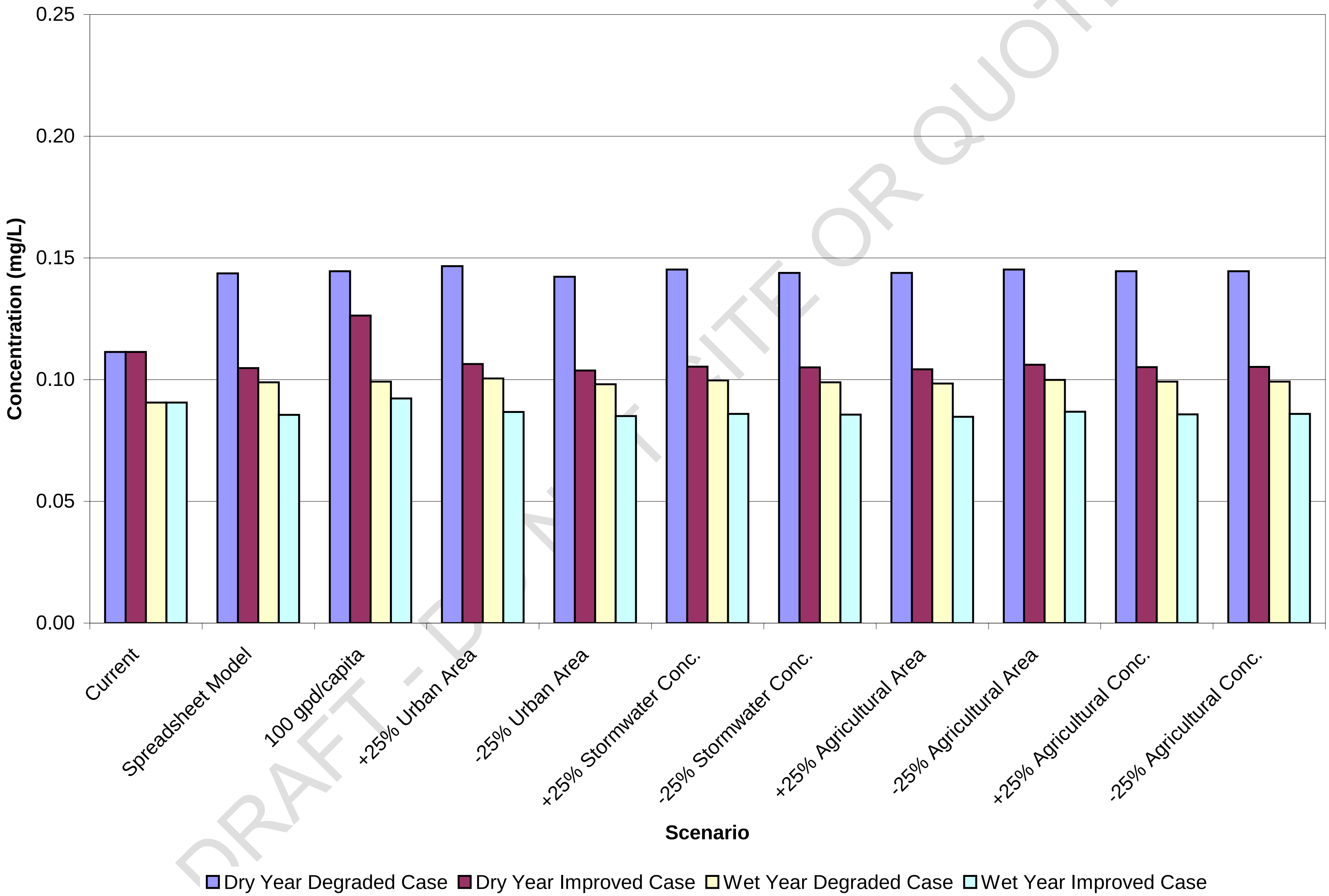


Figure A-5. Projected 2030 Total Phosphorus Concentrations for San Joaquin River at Vernalis from Sensitivity Analyses

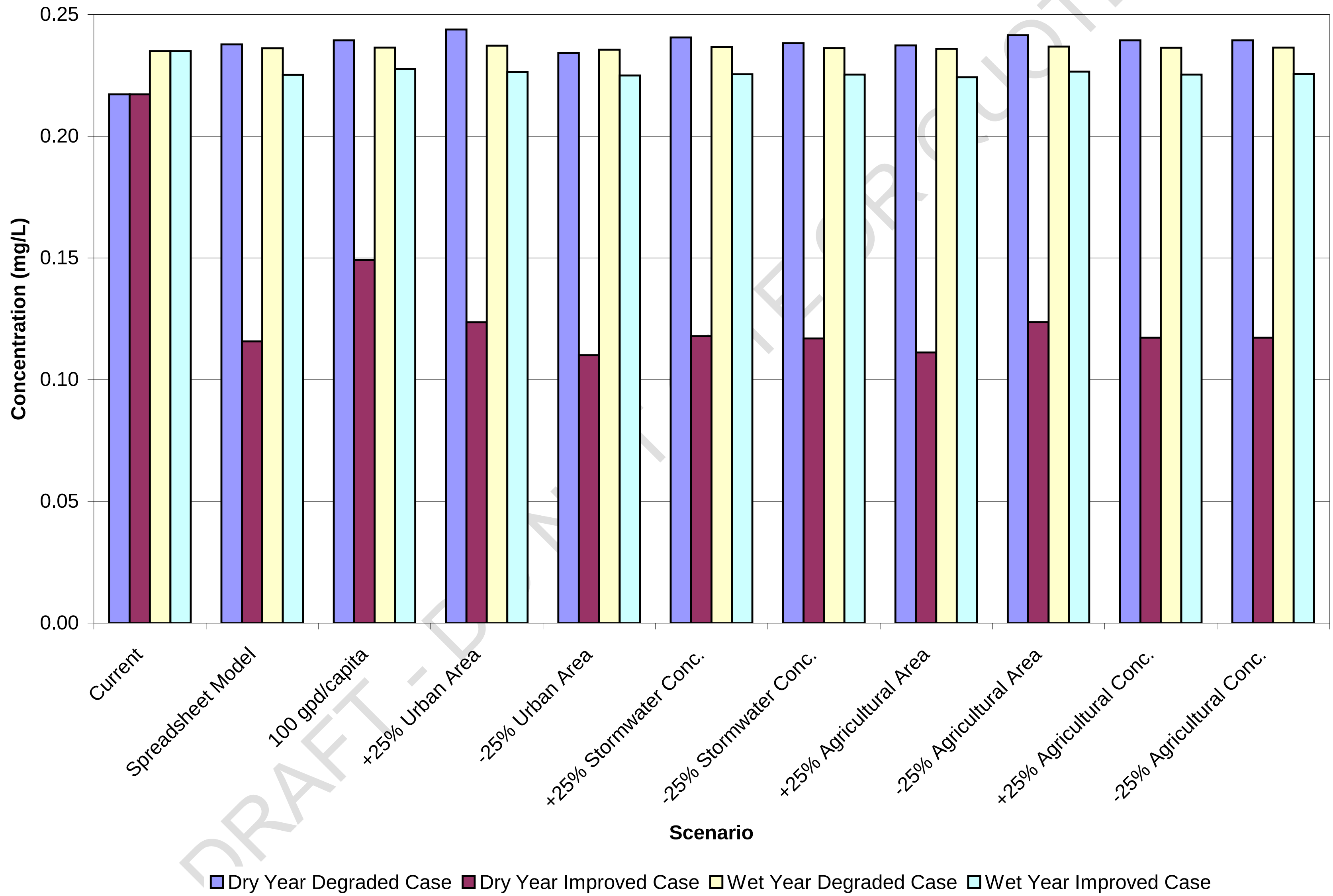


Figure A-6. Projected 2030 Total Phosphorus Concentrations for Banks Pumping Plant from Sensitivity Analyses

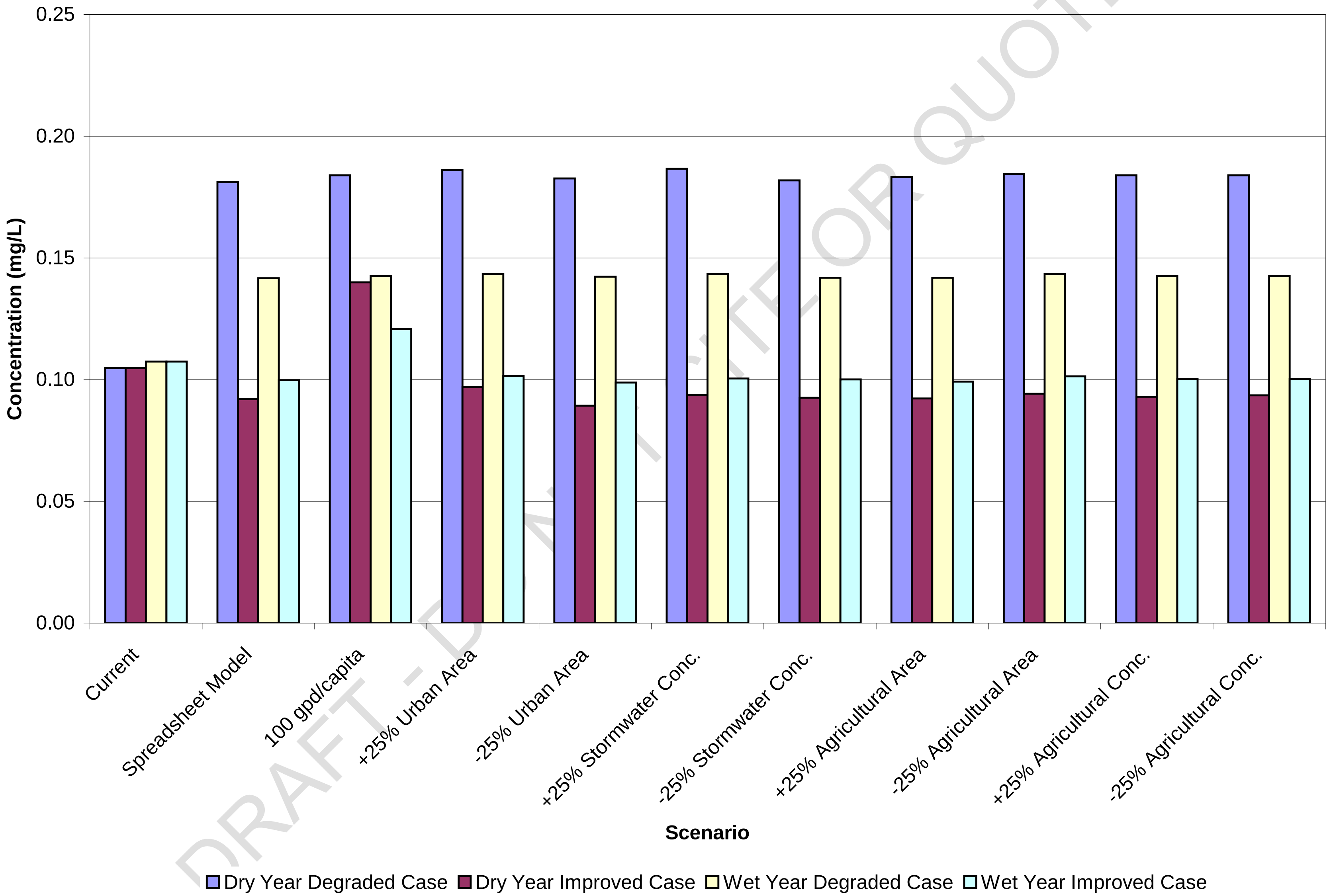


Figure A-7. Projected 2030 Total Nitrogen Concentrations for Sacramento River at Hood from Sensitivity Analyses

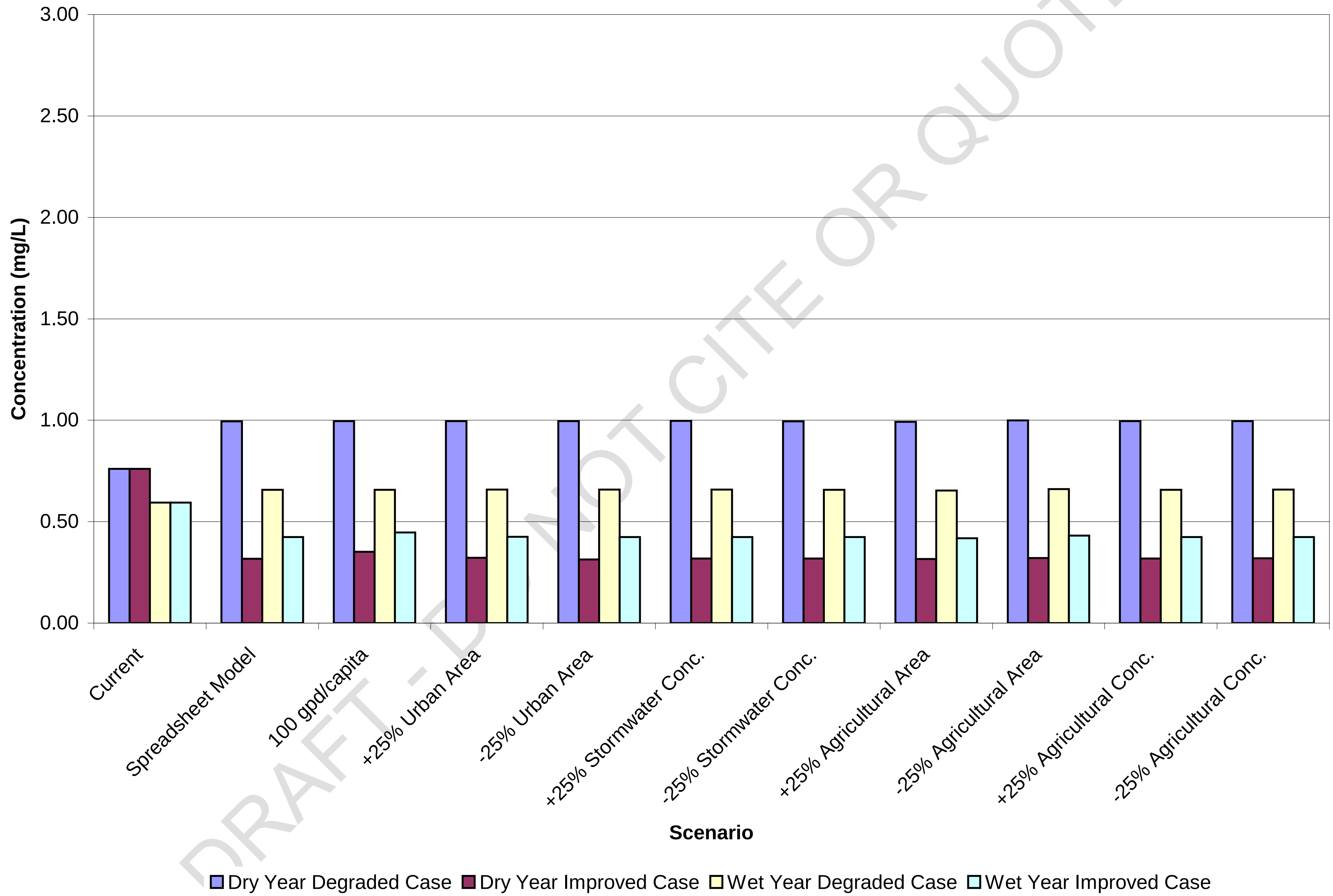


Figure A-8. Projected 2030 Total Nitrogen Concentrations for San Joaquin River at Vernalis from Sensitivity Analyses

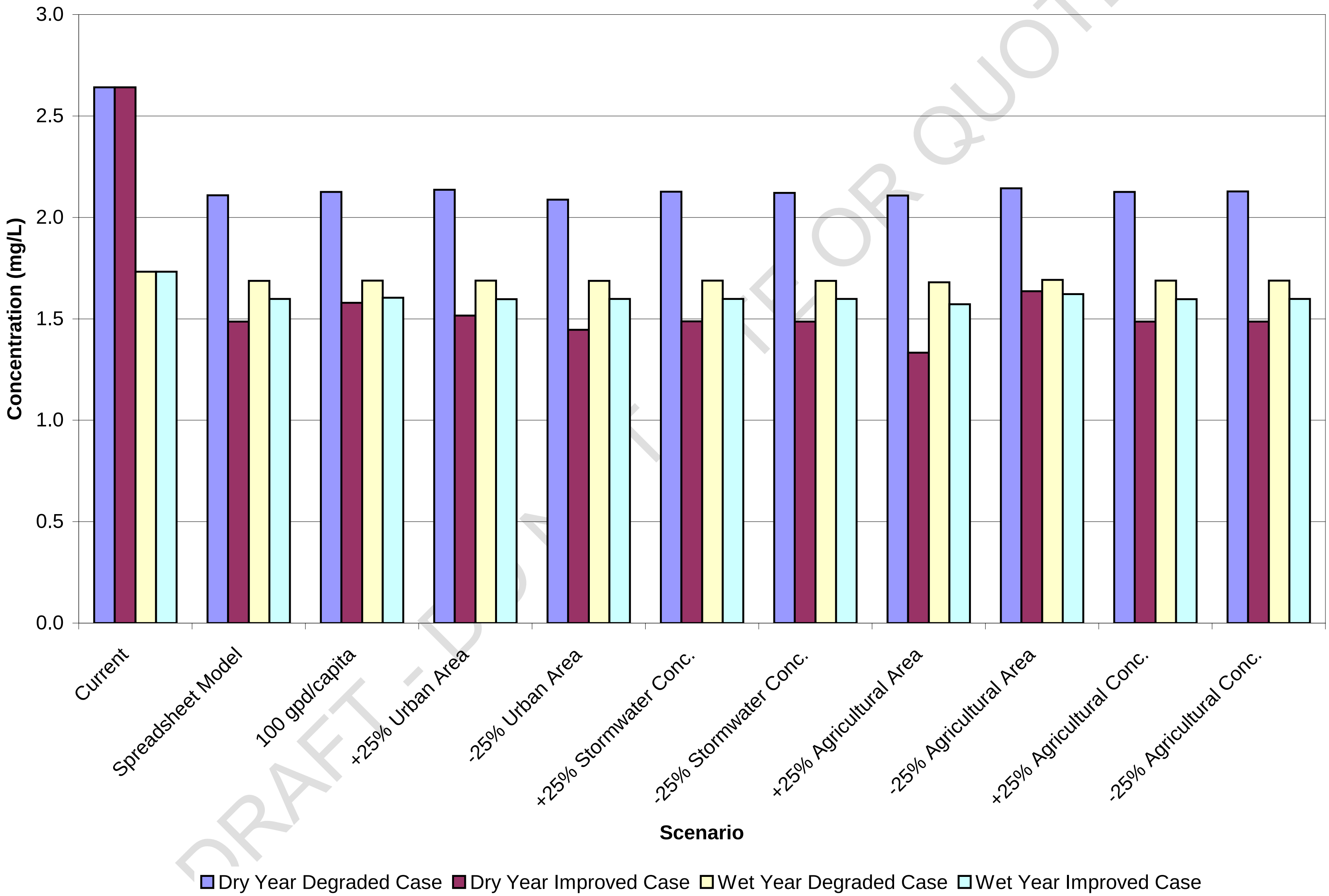


Figure A-9. Projected 2030 Total Nitrogen Concentrations for Banks Pumping Plant from Sensitivity Analyses

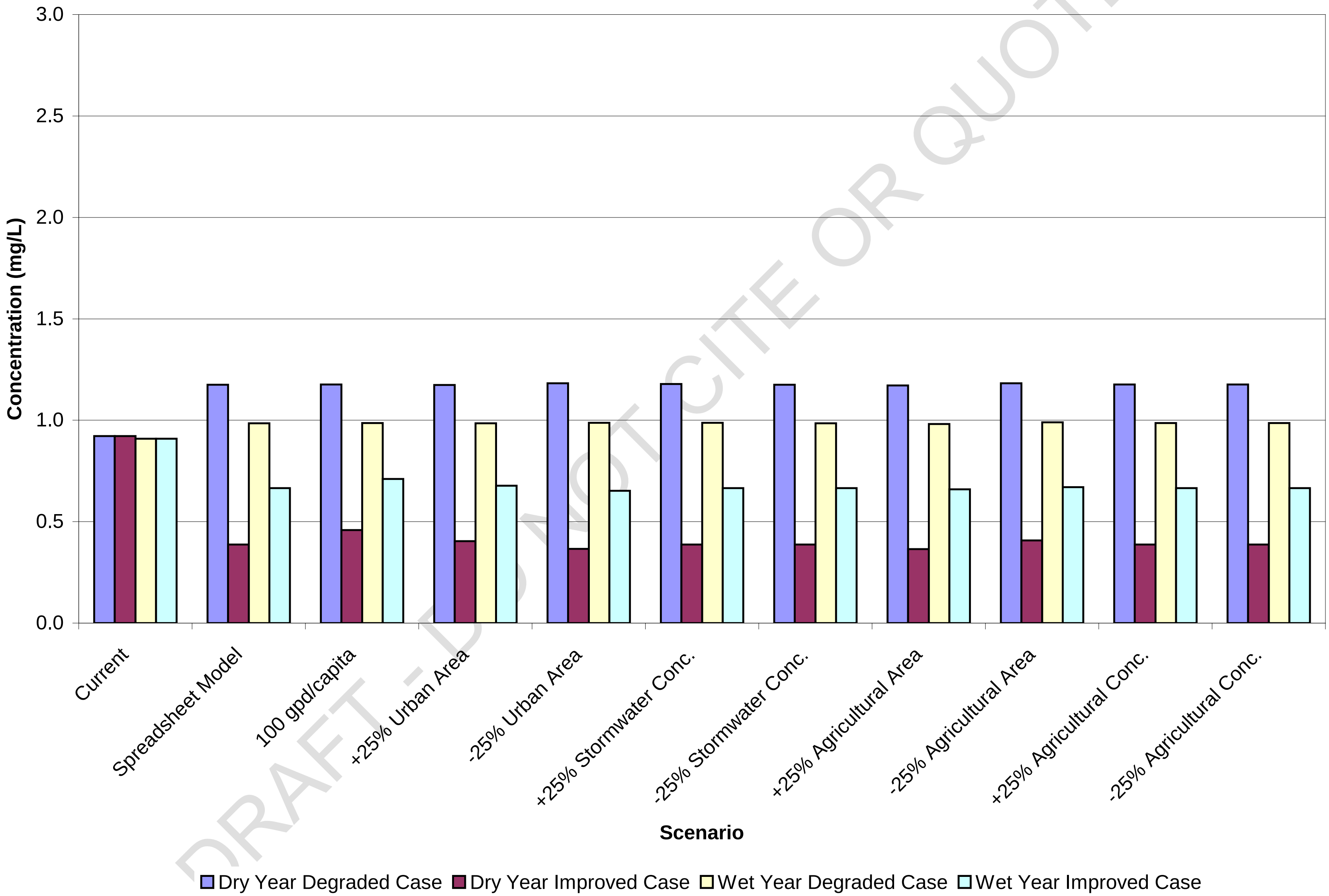


Figure A-10. Projected 2030 Total Dissolved Solids Concentrations for Sacramento River at Hood from Sensitivity Analyses

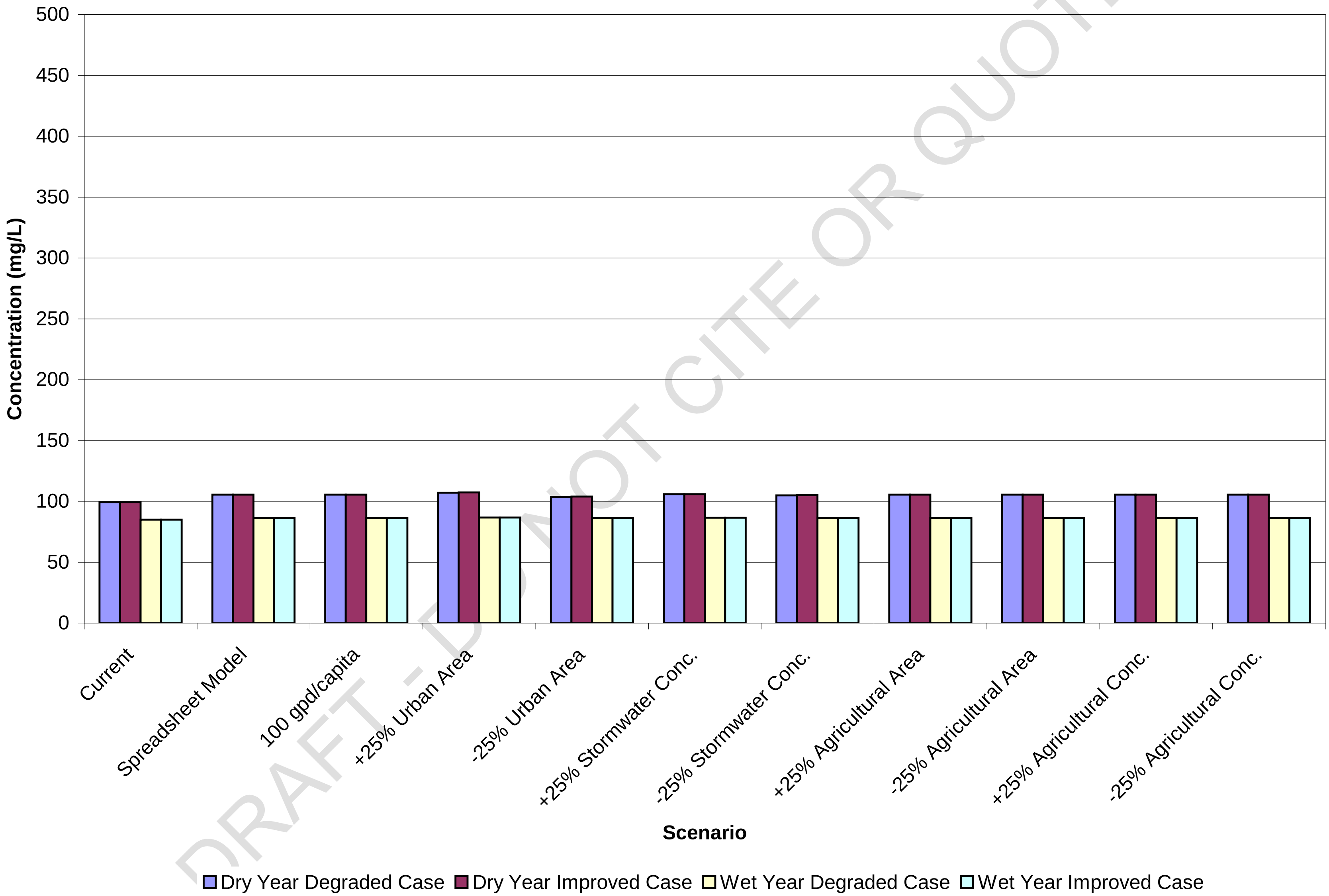


Figure A-11. Projected 2030 Total Dissolved Solids Concentrations for San Joaquin River at Vernalis from Sensitivity Analyses

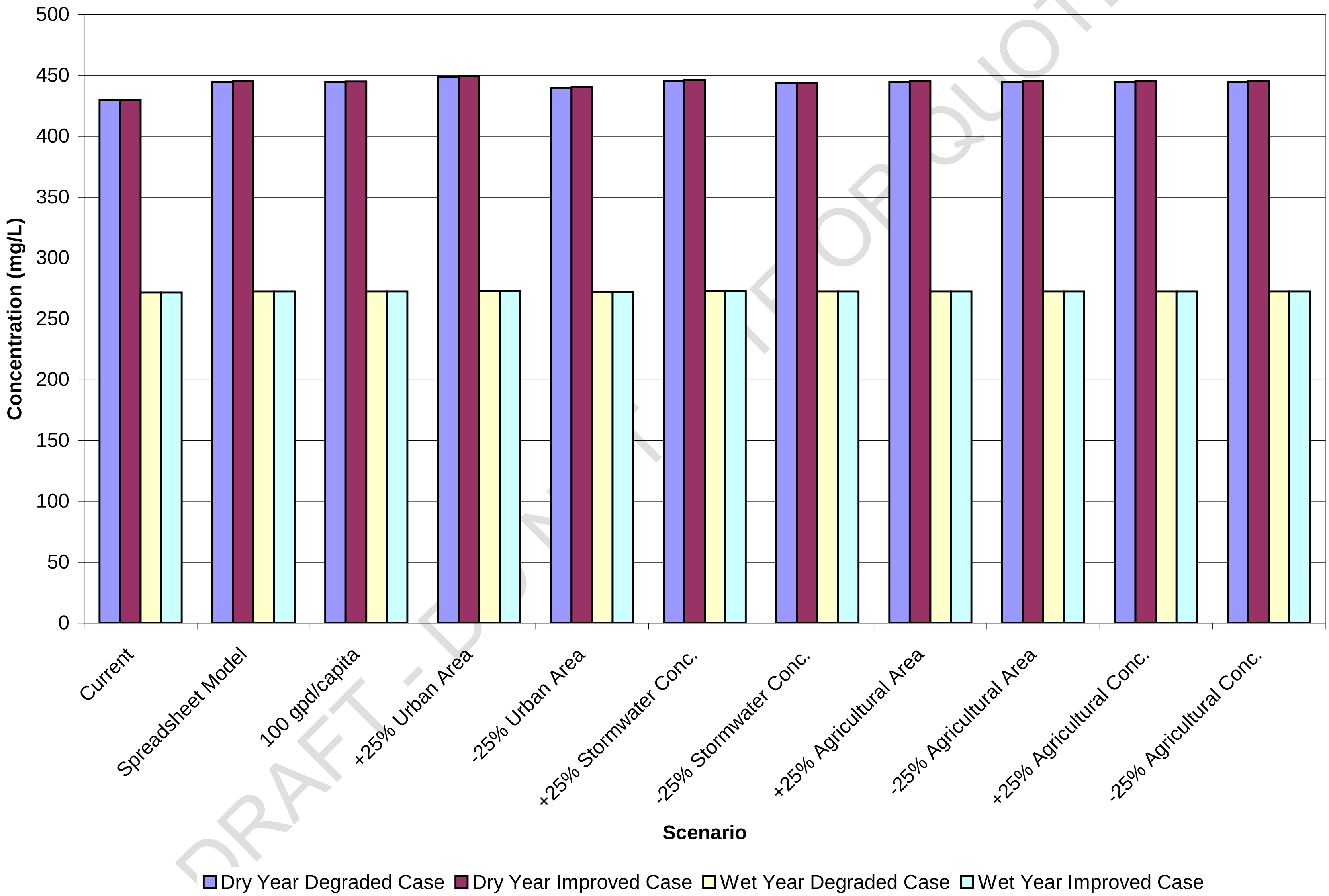
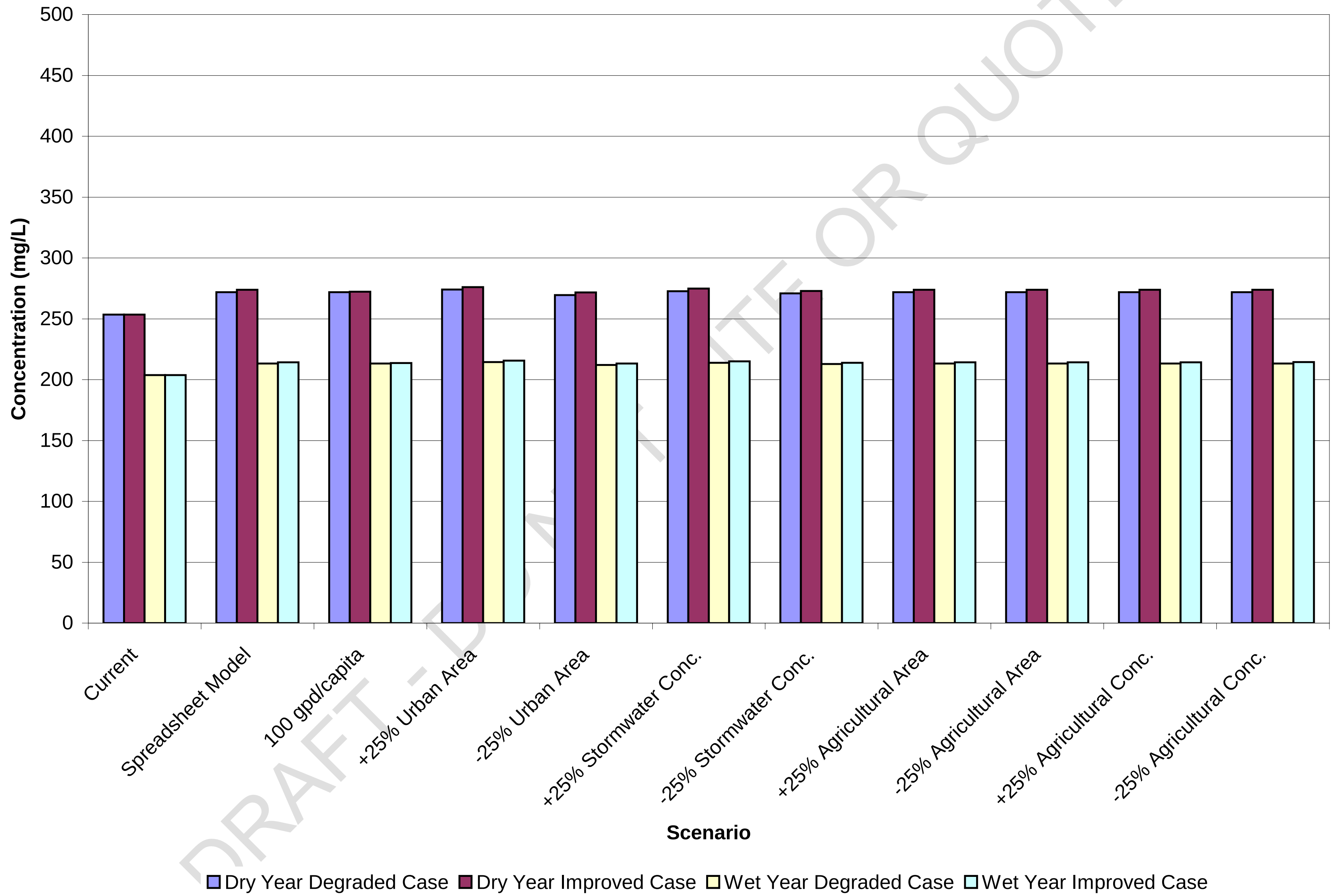


Figure A-12. Projected 2030 Total Dissolved Solids Concentrations for Banks Pumping Plant from Sensitivity Analyses



ATTACHMENT B – WASTEWATER LOADING SAMPLE CALCULATION

This attachment provides the equations, as well as sample calculations, that were used to estimate wastewater loads for the current, projected 2030 degraded, and projected 2030 improved conditions.

Equations Used

$$L_i = 8.345 \times Q_i \times C_i$$

$$P_{i+t} = P_i \times (1+r)^t$$

$$q = \frac{Q_{2004}}{P_{2004}}$$

$$Q_i = q \times P_i$$

$$Q_{2030} = \begin{cases} q \times P_{2030} & \text{Degraded Condition} \\ 0.00008 \times P_{2030} & \text{Improved Condition (80 gallons per day per capita)} \\ 0.0001 \times P_{2030} & \text{Improved Condition (100 gallons per day per capita)} \end{cases}$$

where:

L = constituent load from effluent wastewater sources (lb/day)

Q = effluent wastewater flow rate (MGD)

C = actual/estimated constituent concentration in effluent wastewater sources (mg/L)

If observed effluent data were not available, literature values, depending on treatment type, were used to estimate effluent loads. Literature values used are presented in Table B-1.

Table B-1. Literature Values for Constituents of Concern by Wastewater Treatment Level (in mg/L)

Constituent	Activated sludge	Nitrification/ Denitrification	Filtration	Phosphorus Removal	Ultrafiltration
Total organic carbon	20	20	8	8	8
Total phosphorus	3.4	3.4	2.7	0.8	0.8
Total nitrogen	25	8	8	8	8
Total dissolved solids	Varies (dependent on drinking water source)				

P = population (2004 population from 2004 USEPA Clean Water Needs Survey)

r = annual population growth rate generated from 2004 USEPA Clean Water Needs Survey (population/year)

t = number of years from 2004 (years)

q = daily per capita wastewater flow rate (MGD/capita)

Sample Calculation

This is an example calculation for the City of Davis Wastewater Treatment Plant for TOC.

$$P_{2008} = P_{2004} \times (1 + r)^t = 60{,}308 \times (1 + 0.007)^4 = 62{,}133$$

$$P_{2030} = P_{2004} \times (1 + r)^t = 60{,}308 \times (1 + 0.007)^{26} = 73{,}201$$

$$q = \frac{Q_{2004}}{P_{2004}} = \frac{6.5\,\text{MGD}}{60{,}308} = 0.000108\,\text{MGD/capita}$$

$$Q_{2030} = \begin{cases} q \times P_{2030} = 0.000108\,\text{MGD/capita} \times 73{,}201 = 7.9\,\text{MGD} & \text{Degraded Condition} \\ 0.000080 \times P_{2030} = 0.000080\,\text{MGD/capita} \times 73{,}201 = 5.9\,\text{MGD} & \text{Improved Condition (80 gpd/capita)} \\ 0.0001 \times P_{2030} = 0.0001\,\text{MGD/capita} \times 73{,}201 = 7.3\,\text{MGD} & \text{Improved Condition (100 gpd/capita)} \end{cases}$$

$$L_{2030} = \begin{cases} 8.345 \times Q_{2030} \times C = 8.345 \times 7.9\,\text{MGD} \times 16.3\,\text{mg/L} = 890\,\text{lb/day} & \text{Degraded Condition} \\ 8.345 \times Q_{2030} \times C = 8.345 \times 5.9\,\text{MGD} \times 8\,\text{mg/L} = 390\,\text{lb/day} & \text{Improved Condition (80 gpd/capita)} \\ 8.345 \times Q_{2030} \times C = 8.345 \times 7.3\,\text{MGD} \times 8\,\text{mg/L} = 490\,\text{lb/day} & \text{Improved Condition (100 gpd/capita)} \end{cases}$$